METHOD OF MANUFACTURING VACUUM PUMP ROTORS, AND ROTORS OBTAINED THEREBY

FIELD OF THE INVENTION

The present invention relates to high vacuum turbine pumps and more particularly to a method of manufacturing vacuum pump rotors for a turbomolecular pump as well as to the rotors obtained thereof.

BACKGROUND OF THE INVENTION

Conventional rotor of a turbomolecular pump comprises a group of impellers mounted onto a rotating shaft, each impeller comprising a disk equipped with a set of peripheral radial vanes. During operation, the rotor rotates at peripheral velocity that can be as high as 300m/sec. The severe working conditions and the search for higher and higher performance for turbomolecular pumps, in terms of compression ratio and pumping speed, require that each impeller and the rotor in the whole be made as a structure that is robust and balanced at the same time. Moreover the impeller vanes must be shaped so as to optimize the pump performance.

According to prior art, manufacturing of the rotor starts from an extruded metal bar, from which cylinders are cut that are subsequently processed by different methods, such as turning, milling, electric discharge machining and so on. For instance, according to GB 2 179 942, the impeller is made by forming the blades by milling, by using an apparatus allowing simultaneous processing of several disks.

According to other prior art, it has been proposed to make each vane of the impeller by means of an electric discharge machining technique, as disclosed for instance in FR-A 2 570 970 and US Patent No. 5,188,514.

The known manufacturing methods have certain drawbacks and limitations. In particular, the mechanical properties and the density of the material are not homogenous enough to ensure a long operating life of the rotors. For instance, in rotors manufactured according to prior art technique, the transversal mechanical properties are far worse than the longitudinal properties. Moreover, the longevity of the rotors at elevated temperature is limited. It is of the order of a few hundred hours for a rotor made of aluminium alloy 2014 exposed continuously to temperatures of about 130°C, with equivalent stresses (determined for instance according to the Von Mises failure criterion) of about 300 MPa.

In addition, the manufacturing of such rotors starts from an extruded bar which is subsequently worked. Since commercial bars are available only with standard diameters, it may

be necessary to start from a bar of greater than required diameter and then to reduce the bar size. It would cause additional workings and waste of material.

SUMMARY OF THE INVENTION

Therefore, it is an object of the present invention to provide a method of manufacturing rotors for high vacuum turbomolecular pumps, which overcomes the drawbacks and limitations of the prior art methods. This method allows for obtaining a rotor with homogeneous mechanical properties and material density, with an improved temperature resistance, while avoiding additional workings and waste of material when non-standard diameters of the bars are utilized.

The method of the invention comprises the steps of preparing an intermediate semi-finished piece having homogeneous mechanical properties, which is obtained by forging and subsequent finishing thereof by a conventional mechanical working means.

The method of the invention is especially suitable for obtaining bell-shaped rotors or, in general, non-monolithic rotors with shaft driven into an axial bore.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention, its objects and advantages will become more clearly understood and appreciated with reference to the following detailed description of preferred but not exclusive embodiments, shown by way of non limiting examples when considered in light of the accompanying drawings in which:

Fig. 1 is a diagrammatic view showing the formation of the bar, by forging of a cylindrical billet according to the present invention;

Figs. 2A and 2B are diagrammatic view showing the formation by forging of a bell-shaped billet according to the present invention;

Figs. 3 and 4 are cross-sectional views of two rotors obtained by the method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig. 1, a cylindrical billet 1 is obtained by forging through an axial compression by forces P_l, as schematically shown, while preventing radial expansion through means (not shown) by forces P_r.

In case the rotor is a, so-called, bell-shaped rotor, starting from a bar portion, billet 11 would be first shaped into a substantially cylindrical shape by axial compression by forces P_l as schematically shown in Fig. 2A. Subsequently an axial cavity is formed through a punch 12, by

forcing into billet 11, while preventing the billet radial expansion by retaining it in a mold by applying forces P_r, as shown in Fig. 2B.

Subsequently, billet 11 is mechanically worked by known techniques such as milling, turning, etc., to form the vanes.

In case of manufacturing of bell-shaped rotors, axial cavity 13 is preferably only partly formed by means of the punch by forging, while the remaining part is finished by mechanical working. The axial size of the cavity obtained by means of the punch is usually half of the total height of the billet after forging.

The aluminium alloys commonly used to manufacture turbomolecular pump rotors are alloys 2014 (Al-Cu alloy) and 7075 (Al-Zn alloy) made in the form of extruded bars that are then tempered and aged. According to the present invention, it is still possible to utilize bars of such kind at the beginning of the process, then to cut portions thereof, to forge such portions, to bore them and then to perform a thermal treatment. Forming a central bore on the bottom of the bell-shaped piece obtained by forging allows a further homogenisation of the mechanical properties obtained through the subsequent thermal treatment.

Figs. 3 and 4 show two rotors obtained by the method of the invention. The solid lines show the profile of the bell-shaped billet 11 (intermediate piece) that is subsequently refined by mechanical working. The dashed lines show the profile of the rotor that can be obtained by turning the forged billet.

By manufacturing the rotors of high vacuum pumps, in particular turbomolecular pumps, by forging, according to the method of the present invention the following advantages were observed:

1) A homogenization of the mechanical properties of the rotor, in particular of the tensile ultimate strength R, of the corresponding elongation at break A of the test specimen and of value $R_{0.2}$ (tensile yield strength) at which the tensile strength no longer varies linearly with the corresponding elongation.

It is to be appreciated that the prior art rotors are obtained from extruded bars, in which the above mentioned strength parameters considerably change when passing from the centre to the periphery of the bar. These parameters depend on whether the corresponding cylindrical tensile test specimens are obtained with their axes in the extrusion direction (axis parallel with the bar axis) or perpendicular to such direction (in radial or tangential direction in the bar).

It has been established that, by manufacturing the billets by forging, the values of R, A and $R_{0.2}$ become substantially constant, both in the different points of the piece and in the different directions in which the test specimens for measuring these parameters are obtained.

Moreover the values, corresponding with the highest ones that can be found in the non-forged piece, exhibit little changes from a forged product to another.

These features allow for the utilization of the material, the mechanical properties of which are precisely known and may be introduced during the design phase, without demanding excessively high safety coefficients leading to overdimensioning of the rotor.

Experimental tests carried out by the Applicant have given the following results for aluminium parts presented in Table 1.

Table 1

Extruded bars		Forged billets, all directions
Longitudinal direction	Transversal direction	
R = 480 MPa	R = 400 MPa	R = 480 MPa
$R_{0.2}$ = 420 MPa	$R_{0.2}$ = 350 MPa	$R_{0.2}$ = 420 MPa
A = 8%	A = 2%	A = 8%

It is evident from the experimental data of Table 1 that the rotors obtained from forged parts have, in all directions, properties identical to those of the bars extruded in longitudinal direction.

2) The aluminium alloys further undergo a permanent degradation of the mechanical properties in time with the operating temperature exceeds120-130°C. It was observed that the forged pieces, starting from uniformly higher properties, could also sustain high temperatures for longer periods of time, while retaining a sufficient residual strength with respect to the operating loads.

3) The rotors obtained by the method of the invention exhibit a homogenization of the material density. This feature is of particular interest in parts that have to rotate at high speed (with tangential velocity of the order of 300-400 m/sec), as is the case for rotors of high vacuum turbomolecular pumps.

Therefore, the non-uniform density would lead to a rotor mass that is not distributed in axially symmetrical manner, with negative effects on the balancing. On the contrary, in case of a uniform density, only the effects of geometrical errors (manufacturing and assembling of the rotor components) may request compensation.

4) By means of the forging, a rotor is obtained that is much closer to the final shape, therefore a smaller turning or other mechanical working is required to obtain the finished product.

Though the invention has been described with particular reference to a preferred

embodiment, the invention is not intended to be limited to such embodiment; it may include all changes and modifications that will be evident to the person skilled in the art.